RADIO STATION SITE SELECTION IN A TELECOMMUNICATIONS NETWORK

5   FIELD OF THE INVENTION
    The present invention deals in general with planning
    and/or designing a telecommunications network such as,
    for example, a third-generation cellular network, and in
    particular with selecting a set of physical sites for
10 installing one or more base radio stations.

    BACKGROUND ART
    The selection of physical sites for installing one or
    more radio stations, for example base radio stations, and
15 more specifically the optimum selection of a subset of
    sites from a wider set of candidate sites is a
    significantly relevant aspect in the field of planning,
    designing and developing networks, in particular third-
    generation cellular networks (UMTS), both for network
20 operators that can already be found on the market, and
    for those operators that enter the sector for the first
    time.

    Problems of such nature, in fact, deal both with pre-
25 existing operators owning a network, for example of the
    GSM type, of which the sites available as regards
    installation of new radio stations, for example third-
    generation ones, will be partly or wholly re-used, and
    with new operators that will have to comply with the need
30 of establishing how many cells have to be placed in the
    territory and where they have to be physically located.
    Obviously, even though the present invention preferably
    refers to the cellular network environment, it goes
    without saying that the invention can be used also in the

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wider context of telecommunications networks, particularly, for example, in the fixed networks context that provides for a designing and/or planning that requires a site selection for radio apparatuses.

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As known, in the initial step of installing a complex system such as, for example, a third-generation mobile network and during the normal evolution (enlargement) of the network itself, aim of the operators is serving a
10 specific geographic area complying with the following requirements, that in some cases are mutually in contrast:
- territory electromagnetic coverage;
- carrying the traffic volumes offered by the different
15 active network services;
- limiting the costs due to apparatuses installation and management.

It is therefore important to efficiently determine the
20 set of base radio stations to be used in order to guarantee required performances and obtain a good network development hypothesis in time (the so-called "roll-out") upon increasing the users and deploying services that are more and more numerous, different and complex.

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The prior art where the problem of optimally selecting base radio stations sites has been dealt with comprises United States patent US 6 094 580 assigned to Nortel Networks Corporation, entitled "Method for Optimising
30 Cell-Site Placement", dated 25 July 2000, and the Graduation Thesis prepared in Politecnico of Turin, entitled "Metodo automatico per la pianificazione di una rete UMTS mediante la valutazione di un insieme di siti candidati", Paragraphs 2 and 3 in Chapter 6 and Chapter
35 7, Emanuele Silio, May 2001.

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The method for selecting sites object of patent US 6 094 580 is based on a process structured into two elementary steps in which the following are respectively used:

- Linear Programming Operating Research techniques for defining an initial solution; and
- an algorithm for refining the solution obtained in the previous step, of a non-recurring type.

The used sites selection criteria depend on considerations based on the degree of obtained coverage or service, and on investment costs.

The cost function used for selecting is associated with a problem of minimum and is composed of two different terms, related to economic cost of activated cells/sites and to the cost, expressed through suitable penalties, of traffic (or alternatively geographic area) not served by the resulting network.

After having defined an initial solution obtained through Linear Programming techniques, a "greedy" algorithm operates in order to activate a subset of cells selected in the previous step. Such algorithm iteratively operates by adding a cell/site to every performed elementary step, till a specific stop condition is verified.

The proposed stop conditions are:

1) the selected cell/site does not satisfy a usefulness criterion expressed in terms of cost of incremental traffic that can be carried in case of activation; such cost is expressed by the relationship:

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$$r(s) = \frac{W(s)}{C_S}$$

where:

W(S) is the traffic (in erlang) that can be carried by the cell/site S once activated; and

5   C_S is the cell/site activation cost.

The criterion to be satisfied as regards a new activation is related to the fact that the inactive cell/site, characterised by maximum usefulness r(S), satisfies the

10   relationship:

$$r(s) = \frac{W(s)}{C_S} \geq \frac{Min_{erlang}}{C_S}$$

where the right-hand term in the inequality expresses the minimum increase of carried erlangs normalised with respect to the cell activation cost, that must be

15   satisfied in order to activate the examined cell.

2)   the selected cell/site does not satisfy a usefulness criterion expressed in terms of cost of incremental area that can be covered in case of activation; such cost is

20   expressed by the relationship:

$$r(s) = \frac{A(s)}{C_S}$$

where:

A(s) is the area in square meters that can be covered by the cell/site S once activated; and

25   C_S is the cell/site activation cost.

The criterion to be satisfied for a new activation is related to the fact that the inactive cell/site characterised by maximum usefulness r(S) satisfies the

30   relationship:

$$r(s) = \frac{A(s)}{C_S} \geq \frac{Min_{area}}{C_S}$$

where the right-hand term in the inequality expresses the minimum increase of covered area, normalised with respect to the cell activation cost, that must be satisfied in order to activate the examined cell.

3)   the area globally covered by the system satisfies, after activating the new cell/site, the minimum coverage requirement.

The above three criteria are used as a mutual alternative. Therefore, the site selecting algorithm uses a single stop criterion and the final solution exclusively satisfies the used criterion.

The inconveniences of the proposed solution can be summarised as follows:
- multiple admissibility criteria for the solution are not simultaneously used;
- the criterion in item 1) does not guarantee the compliance with a minimum requirement (or constraint) related to total traffic carried by the set of activated cells (different from 100%);
- the criterion in item 2) does not guarantee the compliance with a minimum requirement (or constraint) related to the area covered by the set of activated cells (different from 100%).

It is important to note how the first mentioned inconvenience is particularly relevant, since it is not adequate to use, for example, the globally carried traffic only in order to judge a good solution, without taking into account the total area covered by the

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considered set of cells. In fact, leaving significantly extended areas, characterised by a scarce offered traffic, uncovered, can be a penalty from the point of view of quality and geographic continuity of services
5 offered to radio-mobile users.

Similar considerations can obviously be made in the completely opposite case in which, as judgement parameter, only the covered area is used, without any
10 type of evaluations related to the traffic actually carried by the system.

The Graduation Thesis "Metodo automatico per la pianificazione di una rete UMTS mediante la valutazione
15 di un insieme di siti candidati" describes a site selecting algorithm based on an approach derived from Operating Search techniques that allows choosing, in order to activate the base radio stations, a subset of sites starting from a wider set of candidates, in which
20 the adopted selection criteria depend on predetermined radio design parameters for third-generation networks.

In more detail, the algorithm operates in order to optimise the resulting coverage depending on parameters
25 such as globally served area, carried traffic and distribution of cell loads η_{cell} and soft hand-over loads η_{SHO} of activated cells.

The relevant algorithm is based on guide lines of a
30 search methodology called "Taboo Search" and uses a cost function of the multidimensional type for evaluating a solution belonging to the space of solutions (the space of solutions corresponds to the complete set of possible solutions), and elementary cells/sites activation and

deactivation moves (actions) that allow exploring the space of solutions to the site selection problem, transforming a solution S1 into a different solution S2.

5   Such algorithm uses, for evaluating the efficiency of a generic solution, a cost function composed of four different terms:

$$F_C = W_1 \cdot A_{NS}^{\%} + W_2 \cdot T_{NS}^{\%} + W_3 \cdot S_C + W_4 \cdot S_{SH}$$

where:

10   W_1, W_2, W_3, W_4 represent the weights associated with each function term; and

the first two cost items A_{NS}^{*} and T_{NS}^{*}, respectively related to the remaining uncovered area and to the remaining traffic not carried by the set of selected
15 cells, assume the following form:

$$A_{NS}^{\%} = \frac{A_{TOT} - \sum_{i=1}^{N_{activecells}} A_i^{service}}{A_{TOT}}$$

$$T_{NS}^{\%} = \frac{T_{TOT} - \sum_{i=1}^{N_{activecells}} \sum_{j=1}^{S} T_j^{(i)}}{T_{TOT}}$$

wherein:

$N_{activecells}$ is the number of cells being present in the
20 solution;

S is the number of services being taken into account;

A_{TOT} is the area covered by the complete set of candidate cells;

T_{TOT} is the traffic carried by the complete set of
25 candidate cells;

$A_i^{service}$ is the area covered by the i-th activated cell; and

$T_j^{(i)}$ is the traffic, of the j-th type, carried by the i-th activated cell, and
30   the further cost items S_C and S_{SH} represent an

indication of the mean square deviation (or standard deviation) of cell loads η^i_{cell} and soft hand-over loads η^i_{SHO} of the activated cells, by ideal load and soft hand-over loads.

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The shown function does not guarantee the definition of a final solution that globally optimises the network planning in the considered geographic area.

The Applicant deems that the global planning optimisation
10 is fundamentally important for providing the services according to minimum capillarity requirements of network on territory, such fact not being guaranteed by the prior art either due to coverage limits or due to traffic limits.

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According to the Applicant, the current prior art therefore has a series of particularly relevant problems related to the impossibility of jointly and efficiently taking into account the design constraints, such as, for
20 example, the minimum geographic area in which the provided services (namely a predetermined volume of traffic) and the minimum traffic to be carried for the set of considered services are guaranteed.

25 Moreover, the Applicant notes that the prior art as a whole does not take into account a particular constraint about the characteristics of the optimum defined solution, namely the predetermination of compulsorily active cells (namely the cells not subjected to the
30 selection process).

The impossibility of deeming as already active, and therefore locked, particular cells, makes the known methods, and in particular those mentioned as most

relevant, unable for preparing the network "roll-out",
within which it is mandatory to take into account the set
of cells already active in the previous years, in order
to develop (enlarge) the network in time.

In the specific context of third-generation mobile
networks, a further limit of the mentioned known prior
art is given by the definition of a cost function to be
minimised, used in the optimisation procedure that does
not allow any evaluation of the possible pilot pollution
phenomenon (interference from pilot channel).

Like every cellular radio-mobile system, the third-
generation UMTS system provides, as known, for common
control channels that are broadcast within the whole area
of each cell. Such channels transmit mandatory system
information for receiver terminals.

Among these, the Common Pilot Channel (CPICH) is a
physical channel in down-link (from radio station to
terminals) that is used by mobile terminals for network
synchronisation. The pilot channel signals operates as
"beacon" to point out the existence of a base station to
network receiver terminals.

Each cell transmits its own pilot signal at a common
frequency; the comparison between signal powers from
different pilot channels allows the terminals to
recognise the server base station and to manage possible
hand-over processes. It is provided that, in particular
areas, called macro-diversity areas, a mobile terminal
decodes the signal from many antennas, and therefore to
exchange information with many Base Radio Stations (SRB).

If a terminal is found in an area in which it receives

the pilot signals from a number of cells greater than the maximum number of cells that can be managed by the terminal and with comparable powers, an interference phenomenon results, known as "pilot pollution", that can
5 generate a decrease transmission capability in the area or also the loss of current calls. The phenomenon also implies a higher consumption of internal terminal power due to the increase of processing needs. In fact, in such situation, the mobile terminal continuously changes the
10 set of cells to which it is connected in macro-diversity (the so-called "active set"), because the number of candidate cells to macro-diversity is greater than the maximum number of cells that can be managed by it.

15 The pilot pollution is therefore an indicator of how many cells in excess are perceived by a radio-mobile terminal when it is connected to a network with respect to its cell managing capability (maximum number of cells to which it can be connected in macro-diversity) and with
20 respect to network parameters.

The evaluation of the pilot pollution phenomenon, related to the system down-link section, is fundamentally important for a good design/planning of a third-
25 generation network, and therefore it must be taken into account in a design/planning context to allow the correct and efficient operation of mobile terminals in the network as designed/planned.

30 SUMMARY OF THE INVENTION

Object of the invention is proposing a method and a system for optimally selecting a subset of sites within a wider set of candidate sites for the activation of one or
35 more radio stations, that allow obtaining a predetermined

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radio-electric and service coverage. This object is reached through a method and a system that allow selecting, as admissible solutions, those solutions that together guarantee both a minimum predefined geographic

5 coverage in which the provided services have to be guaranteed, and a minimum predefined traffic value to be carried for the set of considered services.

   The invention, in a preferred embodiment thereof,
10 proposes a method and a system for selecting a subset of sites that allow predefining, as further constraint on optimum solution characteristics, the compulsorily active cells/sites in the searched solution.

15 The invention also proposed a method and a system for selecting a subset of sites that allow taking into account, in a further preferred embodiment, the pilot pollution phenomenon by minimising the global network impact.
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   In particular, object of the invention are a method and a system for selecting radio stations sites when designing a telecommunications network, whose characteristics are included in the independent claims.
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   Further objects of the invention are a processing program or group of programs for actuating a selecting method, a telecommunication network planning method and a telecommunications networks as claimed.
30

   Synthetically, a meaningful aspect of the method and system of the invention is represented by the joint use of a design constraint related to the minimum area to be covered, computed with respect to the area guaranteed by

35 the configuration with all active sites, and of a design

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constraint related to the minimum traffic to be carried, computed with respect to the traffic guaranteed by the configuration with all active sites, in the search of one or more admissible solutions belonging to the space of
5   solutions, evaluated through a cost function.

A further characteristic is the chance of predefining a plurality of sites to be deemed compulsorily active in any defined solution.
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In order to take into account the pilot pollution phenomenon and to minimise the network presence, the solution of the invention provides for the use of the cost function enriched by a term pointing out the
15 presence of pilot pollution in the system, in addition to introducing new selection criteria for deactivation candidate cells for pilot pollution reasons.

BRIEF DESCRIPTION OF THE FIGURES
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Further advantages and characteristics of the present invention will be better pointed out by the following detailed description, performed with reference to the enclosed drawings, provided as a mere non-limiting
25 example, in which:
        figure 1 shows a schematic example of a sites selecting system according to the invention, with particular reference to inputs and outputs;
        figure 2 is a global flow diagram of the method
30 according to the invention;
        figure 3 is a flow diagram of the procedure for defining an initial solution, identified in the diagram of figure 2;
        figure 4 is a flow diagram of the procedure for
35 building the neighbourhood of solutions "nearby" the

current solution, identified in the diagram in figure 2;
and

        figure 5 is a flow diagram of the algorithm "re-
emerging" procedure, identified in the diagram in figure
5 2.

DETAILED DESCRIPTION OF THE INVENTION

A sites selecting system according to the invention
10 comprises a computerised workstation of a known type (not
shown), or a processing system of the distributed type,
having a processing subsystem and peripheral, local or
remote, input/output devices, and arranged to process
groups or modules of programs stored on disk and
15 accessible on the network. The groups or modules of
programs are processing and computation programs that
realise the method according to the invention that will
be described in detail below. Such workstation or
distributed processing system is deemed well known in the
20 art and will not be further described herein since it is
per se irrelevant in order to carry out and understand
the present invention.

With reference to figure 1, the sites selecting system 10
25 according to the invention comprises a processing module
12 for executing a sites selecting algorithm and an
associated deterministic module 14 for evaluating the
performance of the set of cells generated by the selected
sites. The selecting method of the invention operates
30 through the recursive interaction between processing
module 12 and evaluating module 14.

In the preferred embodiment that provides the
implementation of the method for a third-generation
35 network, the following data are input into the processing

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module 12:

- a first design constraint 20 related to the minimum geographic area in which the provided services must be guaranteed, expressed as percentage of the geographic area covered by all the cells (candidate for the activation) in the area;

- a second design constraint 22 related to the minimum traffic to be carried for the set of services deemed as percentage of the traffic carried by all the cells (candidate for the activation) in the area;

- a relaxation threshold 24 of the constraint 20 on the minimum geographic area to be covered, expressed as percentage, as specified below;

- a relaxation threshold 26 of the constraint 22 on the minimum traffic to be carried, expressed as percentage, as specified below;

- an ideal allotment value 30 between cell load and soft hand-over load, project objective that represents the allotment of cell resources in dedicated resources for traffic controlled by the cell and dedicated resources for macro-diversity traffic;

- a flag 32 pointing out the selection depending on cell or site, that refers to a constraint on optimum solution characteristics; and

- a list 34 of compulsorily active cells that therefore are not subjected to the selection process.

In the preferred embodiment that provides for the implementation of the method for a third-generation network, the following data are input to the evaluation module 14:

- cartography 40 of the area considered by planning, described for example through files stored in a data base that include information such as altimetry, building density and morphology for every territory portion;

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- traffic distribution 42 in the area considered by planning, described for example through files stored in a data base that include information referred to offered traffic, for every type of service, to every territory
5   portion;

- description 44 of candidate cells or sites for activation (namely all cells being present in the considered area) through files containing information related to geographic coordinates, electromagnetic
10 characteristics of used antenna(s), configuration data and family of services supported by every candidate cell or site; and

- the limit cell load 46, project objective that represents the maximum admissible load value for every
15 cell.

In the preferred embodiment, in order to take into account the pilot pollution phenomenon, the following data are provided, for example, to the evaluation module
20 14:

- width 48 of the macro-diversity window of each cell, expressed in dB, pointing out the maximum possible difference between power received on the cell pilot channel and power received on the pilot channel of a cell
25 in macro-diversity therewith; and

- size 49 of the active set of a terminal, that represents the maximum number of cells that can be found in macro-diversity on a territory portion, that can be managed by the terminal.

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The system can provide the following data as output:

- a subset 50 of cells selected for activation;

- the carried traffic (or load) 52 of the selected cells; and

35   - the globally covered geographic area 54.

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In the following description, $N_{candidatecells}$ defines the number of cells being present in the area considered by planning and candidate for activation, and project
5 constraints 20 and 22 are used for determining the minimum area to be covered and the minimum traffic to be carried by the solution obtained at the end of the optimisation procedure. Such quantities are expressed by the relationships:

10

$$A_{\min} = \alpha \cdot \sum_{i=1}^{N_{candidatecells}} A_i^{service}$$

$$T_{\min} = \beta \cdot \sum_{i=1}^{N_{candidatecells}} \sum_{j=1}^{S} T_j^{(i)}$$

where:

α (whose value is included between 0 and 1) corresponds to the constraint 20 on minimum area to be covered with
15 respect to the area guaranteed by the complete set of candidate cells for activation;

β (whose value is included between 0 and 1) corresponds to the constraint 22 on minimum traffic to be carried computed with respect to the traffic guaranteed by the
20 complete set of candidate cells for activation;

S represents the number of types of traffic being taken into account (namely the services);

$A_i^{service}$ and $T_j^{(i)}$ are respectively the covered area and the carried traffic (of the j-th type) by the i-th active
25 cell (in the current case the complete set of $N_{candidatecells}$ candidate cells is deemed active).

Definition and following use of parameters A_{min} and T_{min} allow overcoming the evident prior art limits, because
30 they allow identifying those solutions that comply with both project constraints. Such solutions are called "solutions with Non Relaxed Constraints" (VNR) herein

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below. According to the present description, a generic
solution is defined as VNR type if it complies with the
conditions expressed by the relationships:

$$\begin{cases} A_{Nactivecells}^{service} = \sum_{i=1}^{N_{activecells}} A_i^{service} \geq A_{\min} \\ T_{Nactivecells}^{processed} = \sum_{i=1}^{N_{activecells}} \sum_{j=1}^{S} T_j^{(i)} \geq T_{\min} \end{cases}$$

5 where $N_{activecells}$ are the active cells in the evaluated
solution and $A_i^{service}$ and $T_j^{(i)}$ are, in this case, the
covered area and the carried traffic (of the j-th type)
from the i-th active cell of the considered subset.

10 In addition to the described solutions of the VNR type,
those solutions that do not comply with the coverage and
carried traffic constraints, but that comply with an
admissibility condition relaxed within a predefined
threshold are defined herein below as "solutions with
15 Relaxed Constraints" (VR).

In particular, having defined as δ_α and δ_β the relaxation
admissibility thresholds 24 and 26 on minimum
requirements for covered area and carried traffic, a
20 solution is of the VR type if it complies with the
conditions:

$$(\alpha - \delta_\alpha) \cdot \sum_{i=1}^{N_{candidatecells}} A_i^{service} \leq A_{Nactivecells}^{service} < A_{\min} \qquad \text{and} \qquad T_{Nactivecells}^{processed} \geq T_{\min}$$

or

$$(\beta - \delta_\beta) \cdot \sum_{i=1}^{N_{candidatecells}} \sum_{j=1}^{S} T_j^{(i)} \leq T_{Nactivecells}^{processed} < T_{\min} \qquad \text{and} \qquad A_{Nactivecells}^{service} \geq A_{\min}$$

25 or

$$(\alpha - \delta_\alpha) \cdot \sum_{i=1}^{N_{candidatecells}} A_i^{service} \leq A_{Nactivecells}^{service} < A_{\min} \qquad \text{and}$$

$$(\beta - \delta_\beta) \cdot \sum_{i=1}^{N_{candidatecells}} \sum_{j=1}^{S} T_j^{(i)} \leq T_{Nactivecells}^{processed} < T_{\min}$$

Synthetically, the method of the invention operates in order to select, within a wider set of candidate sites for activating cells in a telecommunications network, for
5 example of the third-generation type, the most suitable cells (or the sites composed of many cells) for providing a satisfactory radio-electric and service coverage.

In order to evaluate the quality of a generic solution
10 and allow, therefore, the comparison between different solutions to the site selection problem, the method uses a cost function within which various cost item types are present and suitably weighed.

15 The function form, of the type known from the Graduation Thesis "Metodo automatico per la pianificazione di una rete UMTS mediante la valutazione di insieme di siti candidati", is expressed by the relationship:

$$F_C = W_1 \cdot A_{NS}^{\%} + W_2 \cdot T_{NS}^{\%} + W_3 \cdot S_C + W_4 \cdot S_{SH}$$

20 in which – as recalled - W_1, W_2, W_3, W_4 represent the weights associated with each function term; the first two cost items $A_{NS}^{\ast}$ and $T_{NS}^{\ast}$ respectively represent, the first one the ratio between the geographic area not served by the subset of cells deemed as active and the area served
25 with all candidate cells active, the second one, similarly, the ratio between traffic not carried by the subset of cells deemed as active and the carried traffic with all candidate cells active. The further cost items, instead, represent an indication of the mean square
30 deviation respectively of cell load η_{cell}^{i} and soft hand-over load η_{SHO}^{i} computed depending, as regards the first one, on the ideal cell load and, as regards the second one, on the ideal soft hand-over load.

In the preferred embodiment, the relationship that expresses the cost function is modified into:

$$F_C = W_1 \cdot A_{NS}^{\%} + W_2 \cdot T_{NS}^{\%} + W_3 \cdot S_C + W_4 \cdot S_{SH} + W_5 \cdot T_{PP}^{\%}$$

in which W_1, W_2, W_3, W_4, W_5 represent the weights associated with each function term, the cost items A_{NS}^{*}, T_{NS}^{*}, S_C and S_{SH} have been defined immediately above and the term T_{PP}^{*} is function of the pilot pollution being present in the system and is expressed by the relationship:

$$T_{PP}^{\%} = \frac{\displaystyle\sum_{i=1}^{N_{activecells}} \sum_{k=1}^{N_{activecells}} \sum_{j=1}^{S} T_{j \leftarrow k}^{(i),PP}}{T_{PP}^{Max}}$$

where $T_{j \leftarrow k}^{(i),PP}$, of a known type, is equal to the j-th service traffic carried by the i-th cell and placed in pilot pollution by the k-th cell.

The parameter T_{PP}^{*} numerator corresponds to the global traffic in pilot pollution associated with the set of active cells being present in the examined solution; the denominator, instead, expresses the maximum pilot pollution that can be found in the system under the worst identifiable conditions for the set of candidate cells for the activation.

The denominator T_{PP}^{Max} is computed as follows:

i)   for each pixel (h,k) of the territory that is electro-magnetically covered by one or more candidate cells:

      - the list ordered by decreasing field levels of the CPICH channel is built depending on the cells in the pixel;

      - if N cells are identified, at the generic i-th step of the computation procedure, the i-th cell of the

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previously built list is taken into account and all cells preceding it in the list are deemed as "turned off"; for the current cell, the number of cells satisfying the following criteria is evaluated:

5   they have such a field level as to enter into the macro-diversity window generated starting from the CPICH channel level of the i-th cell;

      they are not part of the active set of the generic terminal placed in pixel (h,k);

10   - the above-described operation is repeated for all N cells being present in the pixel (i∈[1,N]);

      - the maximum value is collected, indicated with $\text{Num}_{(k,h)}$, among the N elements computed as described;

15 ii) for the area considered by planning, T^{Max}_{PP} is computed through the relationship:

$$T_{PP}^{Max} = \sum_{S_{pixel}} Num_{(h,k)} \cdot T_{(h,k)}$$

where $T_{(h,k)}$ is equal to the total traffic associated with pixel (h,k) and S_{pixel} is the set of pixel of the 20 territory in which there is at least one candidate cell.

In such context, the ideal coverage concept is extended, according to the invention, to the cost item related to pilot pollution that must be, under optimum conditions, 25 equal to 0.

With reference to figure 2, the selection method starts – at step 100 - from evaluating the configuration with the whole set of active candidate cells performed by module 30 14, depending on whose results an initial solution is built - at step 200 - that will be described in detail herein below with reference to figure 3.

As previously mentioned, those solutions composed by

subsets of cells (or sites) that, once activated,
simultaneously comply with project constraints related to
minimum area to be covered and minimum traffic to be
carried are defined as VNR solutions.

The initial solution built in step 200 belongs to such
family of solutions.

Then, in step 300, a storage is performed of the initial
solution obtained as best solution of the VNR type.

After having ended the algorithm initialisation step, the
real optimisation method is performed, that provides for
the iterative application of the below-described
operations.

In a step 400 the neighbourhood of solutions "nearby" the
current solution is generated. Such step is characterised
by its innovative features, since it provides for:
    - building a neighbourhood composed of solutions
"nearby" the current solution obtained both by activating
"inactive" cells, and by deactivating "active" cells;
such characteristic is different from the prior art in
which the neighbourhood was obtained by actuating
individual "alternate" moves (namely with an "alternate"
sequence of an iteration characterised by solutions that
are exclusively obtained through activation moves,
followed by an iteration characterised by solutions that
are obtained exclusively through deactivation moves). The
techniques according to the prior art disadvantageously
brought about a final solution characterised by a number
of active cells that is very similar to the initial
solution one;
    - building a neighbourhood whose size changes in
time; the size, corresponding to the number of evaluated

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solutions, depends on an algorithm memory depending on the path performed when exploring the space of solutions;

- building a neighbourhood whose composition changes in time; the composition, corresponding to the mix of
5 obtained solutions through activation and deactivation moves, depends, also in this case, on an algorithm memory depending on the path performed when exploring the space of solutions.

10 In the preferred embodiment, in order to take into account the pilot pollution, the step of generating the neighbourhood of "nearby" solutions provides for the building of a deactivation neighbourhood depending on the pilot pollution being present in the system.

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Step 400 will be more widely described below with reference to figure 4.

In a step 500 following the completion of step 400 for
20 building the neighbourhood of nearby solutions, the possible need is evaluated for performing a "restore" procedure for a solution. Purpose of such procedure is avoiding stopping in advance the algorithm evolution due to the impossibility of building a non-empty
25 neighbourhood of "nearby" solutions to the current solution.

Such procedure comprises a step 600 for checking, according to known techniques, the solution neighbourhood
30 size; if the neighbourhood is not empty, a step 1000 is started for evaluating the neighbourhood solutions, according to known techniques, otherwise step 700 checks the existence of one or more previously stored solutions available for a "restore".

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If the solution exists, a real "restore" step 800 is performed for the best stored solution and the related evaluation of the solution itself, and then step 400 is re-started for building the neighbourhood of nearby
5   solutions to the current solution.

If the "restore" solution does not exist, a casual solution is built in step 900 through which the optimisation process can be restarted, again closing the
10 cycle at step 400.

In case of cell-based selection (related to the value assumed by parameter or flag 32), the cells deemed as active in the generated casual solution belong to three
15 different subsets, the first one being composed of cells belonging to the list 34 of compulsorily active cells, the second one being composed of cells placed in the "not able to be turned off" status due to a cell load that is higher than a predefined threshold load in the
20 configuration with all active candidate cells, and the third one being composed of casually extracted cells from those not satisfying the criteria described above.

In case of site-based selection, the present step of
25 generating a casual solution implies activating sites that have at least one cell satisfying the described conditions.

Step 1000 performs the evaluation of solutions being part
30 of the neighbourhood of "nearby" solutions to the current solution built in step 400 through the deterministic module 14 for evaluating performances of a set of network cells.

35 After the evaluation of neighbourhood solutions, a step

1100 is performed for storing the interesting solutions. These latter ones belong to three different types:

- optimum solution with not relaxed constraints (optimum VNR);

5 - optimum solution with relaxed constraints within predefined thresholds (optimum VR);

- best second choice discarded during each algorithm iteration.

10 Such step provides - in step 1200 - the check for the existence of (one or more) solutions of the VNR type in the evaluated neighbourhood. If some exist, the check is performed - in step 1300 - for the existence of one or more solutions with non relaxed constraints that improve

15 the optimum of the VNR type (namely the solution cost) and, if there is at least one of them, storing of the best solution is performed - in step 1400. If there is no VNR solution (checking step 1200) or if the identified solutions do not improve the VNR-type optimum (checking

20 step 1300), and anyway downstream of the possible storing in step 1400, a step 1500 is performed for checking the existence of VR solutions.

If there are one or more solutions with relaxed

25 constraints within prefixed thresholds (VR) in the neighbourhood, the check is performed - in step 1600 - for the existence of one or more solutions that improve the VR-type optimum (namely the solution cost), and, if there is at least one of them, storing of the best

30 solution is performed - in step 1700. If there is no VR solution (checking step 1500) or if the identified solutions do not improve the VR-type optimum (checking step 1600), and anyway downstream of the possible storing in step 1700, a step 1800 is performed for checking the

35 existence of at least one discarded solution belonging to

25

the neighbourhood of solutions.

If there are one or more solutions of such type, storing of the best among them is performed - in step 1900; if there is no discarded solution (checking step 1800), and anyway downstream of the storing in step 1900, a step 2000 is performed for selecting the best solution belonging to the neighbourhood evaluated as new current solution.

The solution stored in step 1900 is the solution that the algorithm can "restore" as described above, in step 800. The stored solutions in steps 1400 and 1700 are output from the processing module 12 at the end of the algorithm execution as subset 50 of cells selected for activation.

The selection in step 2000 occurs depending on the value assumed by the cost function of the evaluated solutions. During such step, the type of performed move is further verified: if this latter one is of the same type as the one performed during the previous iteration, a counter N_{cons} (whose value is equal to the number of consecutive iterations performed by carrying out the same type of move) is increased by one unit, otherwise the same counter is set to value 1.

Afterwards, a step 2100, updated according to the invention, for checking the selection algorithm ending conditions provides - in step 2200 - for the check of provided ending conditions, such as, for example, the completion of the granted processing time or the obtainment of an absolute optimum (null cost function). If at least one of the output conditions is verified, the algorithm stops, in step 2300, its own evolution, otherwise step 2400 is carried out.

26

After having ended the neighbourhood exploration for the
current solution in step 2000 and having checked the
algorithm output conditions in step 2100, step 2400,
peculiar characteristic of the invention, is performed
for monitoring and implementing an algorithm "restore"
procedure.

Such step provides – in step 2500 - for a check of the
existence of at least one VNR or VR solution in the
neighbourhood evaluated in steps 1000 and 2000. In case
of an affirmative reply – in step 2600 - a counter is
reset of the number of consecutive iterations performed
without evaluating at least one solution of the VNR or VR
type (namely far from the admissibility area – namely
from VNR solutions - or almost admissibility area –
namely from VR solutions - of the space of solutions),
and step 400 for building a new neighbourhood is
afterwards restarted. In case of negative reply - in step
2700 - the above counter is increased and then, in step
2800, a comparison is made between the value present in
the relevant counter and the maximum admissible number of
iterations far from the admissibility or quasi-
admissibility area of the space of solutions.

If such value has been reached, a step 2900 is performed
for carrying out the real algorithm "restore" procedure,
downstream of which the above counter is reset (in step
3000) and step 400 for building a new neighbourhood is
afterwards restarted; otherwise step 400 is directly
performed.

The "restore" procedure in step 2900 allows obtaining
with certainty a solution with complied-with constraints
starting from the selected solution in step 2000, and

this will be described more in detail below with
reference to figure 5.

The individual procedures for building the initial
5 solution, the neighbourhood of nearby solutions to the
current solution and the algorithm "restore", mentioned
in the previous disclosure, will be described below.

The procedure for building an initial solution

10

With reference now to figure 3, the procedure 200 is
described for building an initial solution, of the VNR
type, with reference to the cell-based selection
established by parameter 32. In case of site-based
15 selection, instead, the below described operations based
on cells are extended to all sites having at least one
cell satisfying the described conditions.

Purpose of procedure 200 is determining a VNR-type of
20 solution to be optimised in the following steps and that
as a minimum contains, as active cells, the compulsorily
active cells and the cells deemed as "not able to be
turned off".

25 In a sub-step 205 a "type 0" solution is built and
evaluated (by computing its own cost function), obtained
by activating the cells belonging to the list 34 of
compulsorily active cells and the cells deemed as "not
able to be turned off" due to a cell load that is higher
30 than a predefined threshold load in the configuration
with the complete set of active candidate cells (computed
in step 100).

In step 210 it is checked whether solution "0" belongs to
35 the set of VNR-type solutions; if the check result is

positive, step 260, of a known type, is performed for exiting the initial solution defining procedure, otherwise step 215 is performed for building a "I-type" initial solution. The "I-type" initial solution is build

5 by activating cells belonging to the list 34 of compulsorily active cells, the cells placed in the "not able to be turned off" status due to a cell load that is higher than a predefined threshold load in the configuration with all active candidate cells and the

10 cells placed in the "able to be turned off" status due to a cell load that is lower than a predefined threshold load in the configuration with all active candidate cells, but not having in such configuration any adjacent cell in soft hand-over.

15

In step 220, similarly to step 210, it is checked whether solution "I" belongs to the set of VNR-type solutions; if the check result is positive, step 260 is performed for exiting the initial solution defining procedure,

20 otherwise the procedure proceeds to step 225 for checking the solution characteristics with the complete set of active cells.

If the average load of cells in the configuration with

25 the complete set of active candidate cells is greater than the predefined threshold load, step 230 is performed, otherwise step 235 is performed, for building new solutions.

30 In step 230 a "II-type" solution is built, while in step 235 a "III-type solution is built".

The "II-type" solution is built by activating the cells belonging to the list 34 of compulsorily active cells,

35 the cells placed in the "not able to be turned off"

status due to a cell load that is higher than a
predefined threshold load in the configuration with all
active candidate cells, the cells placed in the "able to
be turned off" status due to a cell load that is lower
5   than a predefined threshold load in the configuration
with all active candidate cells, but not having in such
configuration any adjacent cell in soft hand-over, and
the cells candidate to "capture" (since characterised by
a low load or traffic) the associated load, in the
10 configuration with all active candidate cells, to the
cells to be deactivated (namely the cells "able to be
turned off" with one or more adjacent cells in soft hand-
over in the configuration with all active candidate
cells).

15

The "III-type" solution is built by activating the cells
belonging to the list 34 of compulsorily active cells,
the cells placed in the "not able to be turned off"
status due to a cell load that is higher than a
20 predefined threshold load in the configuration with all
active candidate cells, the cells placed in the "able to
be turned off" status due to a cell load that is lower
than a predefined threshold load in the configuration
with all active candidate cells, but not having in such
25 configuration any adjacent cell in soft hand-over, and
the cells candidate to "capture" (since characterised by
a high adjacency parameter in soft hand-over) the
associated load, in the configuration with all active
candidate cells, to the cells to be deactivated (namely
30 the cells "able to be turned off" and with one or more
adjacent cells in soft hand-over in the configuration
with all active candidate cells).

In step 240, similarly to steps 210 and 220, it is
35 checked whether solution "II" or solution "III" belong to

the set of VNR-type solutions; if the check result is
positive, step 260 is performed for exiting the initial
solution defining procedure, otherwise step 245 is
performed for building the type IV', IV'' and IV'''
5 solutions.

The three referred-to solutions are defined as follows:

- *Solution IV'*

10

The subset of cells is selected, placed in the "able to
be turned off" status (composed of M_{max} elements)
downstream of the configuration evaluation with the
complete set of active candidate cells, then, for each
15 selected cell, the sum $S_{A\&T}$ is computed of the percentages
of covered area with respect to total covered area with
the configuration of all active candidate cells, and the
carried traffic with respect to the total carried traffic
under the configuration with all active candidate cells.

20

Afterwards, an ordered list by increasing $S_{A\&T}$ is built of
the M_{max} selected cells.

Among the identified cells, the one to which the minimum
25 of parameter $S_{A\&T}$ is associated, is selected and placed in
the "turned off" status if, following its deactivation,
the remaining covered area and carried traffic satisfy
the project constraints.

30 If downstream of the selection, there are no further
cells in the "able to be turned off" status, or at least
one of the project constraints is not observed, the
process ends, otherwise the selection step is repeated.

35 Through the described procedure, the first M'_{IV} cells

(with $M'_{IV} \leq M_{max}$) of the list ordered by increasing $S_{A\&T}$ are deactivated.

It must be noted how the thereby obtained solution surely
5 complies with the project constraints, since a decrease of the covered area and the carried traffic is evaluated that is equal to the covered area and the carried traffic, in the configuration with all active candidate cells, by the cell being turned off. Such assumption is
10 conservative since part of the area and traffic left uncovered of the cell placed in the "turned off" status is acquired by one or more cells that are still active in the resulting system.

15 - *Solution IV''*

The subset of cells is selected that are placed in the "able to be turned off" status (composed of M_{max} elements) downstream of the configuration evaluation with the
20 complete set of active candidate cells, then a list of the M_{max} selected cells is composed, ordered by increasing carried traffic in the configuration with the complete set of active candidate cells.

25 Among the identified cells, the one to which the minimum carried traffic is associated, is selected if, after its deactivation the remaining carried traffic satisfies the related project constraint.

30 If downstream of the selection, there are no further cells in the "able to be turned off" status or the constraint is not observed, the process proceeds to the following step, otherwise the selection step is repeated.

At the end of the selection of "able to be turned off"
cells to which the minimum carried traffic is associated,
a list is built ordered by increasing covered area of the
T (with T $\leq$ M_{max}) cells selected through the described
5   criterion.

Then, among the previously identified T cells, the cell
is selected with which the minimum covered area is
associated and this is "turned off" if, after turning
10 off, the remaining coverage satisfies the related project
constraint. If there are no further cells in the list of
T elements, or if the constraint has not been observed,
the process ends, otherwise the selection step by covered
area is repeated.
15

Through the described procedure, M''_{IV} cells (with $M''_{IV} \leq$
T $\leq$ M_{max}) are deactivated.

Also in this case, there remains valid what has been
20 stated for the initial solution of the IV' type about the
conservative estimations related to decrease of the
guaranteed coverage and the carried traffic by the still-
active cells in the resulting system.

25 - *Solution IV''''*

The subset of cells is selected that are in the "able to
be turned off" status (composed of M_{max} elements)
downstream of the configuration evaluation with the
30 complete set of active candidate cells, then a list of
the M_{max} selected cells is built, ordered by increasing
covered area in the configuration with the complete set
of active candidate cells.

33

Among the identified cells, the one with which the minimum covered area is associated, is selected if, after its deactivation, the remaining covered area satisfies the related project constraint.

If, downstream of the selection, there are no further cells in the "able to be turned off" status or the constraint is not observed, the process proceeds to the following step, otherwise the selection step is repeated.

At the end of the selection of "able to be turned off" cells with which the minimum covered area is associated, a list is built ordered by increasing carried traffic of the A (with A ≤ M_{max}) cells selected through the described criterion.

Then, among the A previously identified cells, the cell with which the minimum carried traffic is associated, is selected and "turned off" if, after turning off, the remaining carried traffic satisfies the related project constraint. If there are no further cells in the list of A elements or if the constraint is not observed, the process ends, otherwise the selection step is repeated by carried traffic.

Through the described procedure, M'''_{IV} cells (with $M'''_{IV} \le A \le M_{max}$) are deactivated.

Also in this case, there remains valid what has been stated for the previous cases about the conservative estimations related to decrease of the guaranteed coverage and the carried traffic by the still-active cells in the resulting system.

After building the type IV', IV'' and IV''' solutions, in
step 250 the solution that, among the described IV', IV''
and IV''' solutions, minimises the number of active
5   cells, is selected.

In step 255 the selected "IV-type" solution is evaluated
(by computing its own cost function), and in step 260 the
initial solution defining procedure ends.
10

The procedure for building a neighbourhood of nearby
solutions

Referring now to figure 4, the procedure for building the
15 neighbourhood of "nearby" solutions to the current
solution is described in detail.

In step 405 an evaluation is performed about the
usefulness of a step for increasing the neighbourhood
20 sizes (intensification step); the solution obtained
during a previous iteration or the initial solution
obtained at the first iteration is deemed interesting in
order to intensify the local search if:
- it has or represents a relative minimum for at least
25 one of the cost function terms; or
- it has or represents a relative minimum as regards the
number of active cells or sites; or
- it is an optimum of the VNR type; or
- it is an optimum of the VR type.
30

If the solution obtained in the previous iteration is
deemed interesting in step 405, a step 410 is performed
for selecting the building of a neighbourhood of the
current solution with "high" sizes, namely containing a
35 number of solutions that is equal to at least twice a

neighbourhood of "standard" sizes as defined below. If the obtained solution in the previous iteration is not deemed interesting in step 405, a step 415 is performed for selecting the building of a neighbourhood of the

5   current solution whose sizes, in terms of number of solutions, are empirically determined, for example depending on the available processing time and the problem sizes (number of candidate cells or sites). Such number of solutions is called here neighbourhood with

10   "standard" sizes.

In step 420, following step 410 or 415, the types of moves performed in the previous algorithm iterations are checked. If the last N_{max} moves do not belong to the same

15   type (condition verified for $N_{cons} < N_{max}$, where N_{cons} has been defined previously), step 425 is performed, otherwise step 430 is performed.

Step 425 implies building a neighbourhood of the so-

20   called "A type", comprising solutions obtained both through activation moves and through deactivation moves.

In step 430 the belonging type of moves performed during the last N_{max} iterations is checked and, if the considered

25   moves are of the activation type, step 435 is afterwards performed, otherwise step 440 is performed.

Step 435 implies building a neighbourhood of the so-called "B-type", comprising solutions exclusively

30   obtained by performing activation moves.

Step 440 implies building a neighbourhood of the so-called "C-type", comprising solutions obtained by performing deactivation moves.

35

36

After having built a neighbourhood of the B or C type respectively occurred in step 435 or 440, in step 445 the counter of consecutive iterations characterised by neighbourhoods of the single-move type, namely composed of solutions obtained by exclusively performing moves of a same type, is incremented.

After having performed the update of the above counter in step 445, the algorithm advances to step 450 for checking the type of used neighbourhood. If the neighbourhood is obtained through moves of the same type (B- or C-type neighbourhood) step 455 is performed, otherwise the iteration is deemed as ended and the algorithm proceeds to step 600.

Step 455 verifies whether the maximum number of consecutive iterations, characterised by neighbourhoods of the single-move type, has been reached. If the predefined limit is not reached, the iteration is deemed as ended and the algorithm proceeds to step 600; otherwise, in step 460, the above counter is zeroed and the counter of the number N_{cons} of consecutive iterations performed by executing the same type of move is set to $N_{max}-1$; at the end of such step, the iteration is deemed as ended and the algorithm proceeds to step 600.

The criteria for selecting the cells to be activated are of a known type. The cells to be activated are those that could result useful in order to remove the coverage and/or traffic holes or the support to cells adjacent thereto characterised by very high cell load (η^{i}_{cell}) values; in particular, the selected cell C_x for the activation must:

   - be deactivated in the current solution S_i; and

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- have, in the configuration with all active candidate cells, an adjacent cell C_y in soft hand-over and therefore a very high soft hand-over adjacency parameter Adj_{SH}^{Cx-Cy} towards the cell C_y itself; in addition
5   to this, the cell C_y in the current solution S_i must be characterised by a high cell load value, that points out the need for activating a cell C_x adjacent thereto that can "capture" part of the carried traffic associated therewith.

10

Parameter Adj_{SH}^{A-B} represents the so-called soft hand-over adjacency between a pair of cells. In more detail, the soft hand-over adjacency between two cells A and B corresponds to a percentage computed as ratio between the
15   macro-diversity area of the two cells and the global service area, sum of the service areas in A and B, and is expressed by the relationship:

$$Adj_{SH}^{A-B} = \left(\frac{A_{A-B}^{macro-diversity}}{A_A^{service} + A_B^{service}} \right) * 100$$

20 The criteria for selecting the cells to be deactivated can generally be of a known type. In such case, the cells to be deactivated are those characterised by very low cell load (η_{cell}^i) values; in particular, the cell C_x selected for deactivation must also:
25   - be active in the current solution S_i; and
           - have a high value of the soft hand-over adjacency parameter Adj_{SH}^{Cx-Cy} towards an active cell C_y not excessively loaded in the current solution; in such case, by deactivating cell C_x, cell C_y "captures" a meaningful
30 part of the previously carried traffic by the deactivated cell.

In the preferred embodiment in which the pilot pollution

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phenomenon is taken into account, the deactivation neighbourhood building is, instead, innovative. If N_{deact} are the cells to be selected for the possible deactivation, the current neighbourhood building
5 procedure depends on the presence of the pilot pollution in the system and is structured into two preliminary sub-steps and a final selection step as follows.

- *Selection sub-step per cell load*

10

Active cells in current solution S_i are ordered by increasing cell load, and, among those that have still not been analysed, the cell C_x is identified that satisfies the following requirements:
15   - it is active in the current solution S_i;
          - it is in the "able to be turned off" status;
          - it is characterised by the minimum cell load.

If no cell has been identified, the selection process
20 stops; otherwise, the identified cell C_x is selected for deactivation if it has at least one adjacent cell in soft hand-over in the current solution with cell load lower than the maximum load; in such case, the adjacent cell C_y characterised by the highest value of parameter Adj_{SH}^{Cx-Cy} in
25 solution S_i is placed in the "not able to be turned off" status for the remaining part of the selection step.

If there is no adjacent cell in soft hand-over in the current solution, cell C_x is discarded and a further cell
30 C_x is searched among those that have not yet been examined. Otherwise, it is checked whether the number of selected cells for building the deactivation neighbourhood (sub-neighbourhood) per cell load is equal to N_{deact}; if the reply is affirmative, the process stops,

otherwise a further cell C_x is searched among those that have not yet been examined.

- *Selection sub-step per pilot pollution*

5

Active cells in current solution S_i are increasingly ordered depending on the parameter expressed by the relationship:

$$A_{pp} = \frac{\sum_{i=1}^{N_{activecells}} T_{i \leftarrow Cx}^{PP}}{T_{Cx}^{TOT}}$$

10 where $T_{i \leftarrow Cx}^{PP}$ is the carried traffic by the generic i-th cell placed in pilot pollution by cell C_x, $N_{activecells}$ is the number of active cells in the evaluated solution and T_{Cx}^{TOT} is the globally carried traffic by cell C_x.

15 The A_{pp} numerator expresses the advantage, in terms of pilot pollution decrease, deriving from the cell C_x deactivation, while its denominator expresses the potential disadvantage, related to the same cell deactivation, assuming that all traffic carried thereby
20 goes to pilot pollution downstream of the deactivation.

Then, among those that have not yet been analysed, the cell C_x satisfying the following requirements is identified:
25   - it is active in the current solution S_i;
          - it is in the "able to be turned off" status;
          - it is characterised by the maximum value of parameter A_{pp}.

30 If no cell is identified, the selection process stops; otherwise, the identified cell C_x is selected for deactivation if it has in soft hand-over adjacency, in

40

the current solution, a set of base radio stations that
are able to "capture" the cell load η_{cell} left free
downstream of the deactivation of C_x. In such case, the
adjacent cells in soft hand-over placed in the "able to
5   be turned off" status in solution S_i pass from the "not
able to be turned off" status for the remaining part of
the selection step.

If there are no adjacent cells able to "capture" what has
10 been previously carried by the base radio station C_x, the
identified cell is discarded and a further cell C_x is
searched among those that have not yet been examined.

Otherwise, it is checked whether the number of selected
15 cells for building the deactivation neighbourhood (sub-
neighbourhood) for pilot pollution is equal to N_{deact}; if
the reply is affirmative, the process stops, otherwise a
further cell C_x is searched among those that have not yet
been examined.
20

- *Final selection sub-step*

The set of N_{deact} cell to be taken into account for their
possible deactivation is built starting from the sets
25 defined depending on cell load and pilot pollution
conditions; the final selection procedure is structured
as follows:
        - if the global number of selected cells in the two
previous sub-steps is not greater than N_{deact}, the
30 deactivation neighbourhood is built by using the complete
set of previously-identified cells;
        - if the global number of selected cells in the two
previous sub-steps is greater than N_{deact} the following
steps are performed:

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those cells identified both in the first and in the second sub-step (namely in common between the two sets) are selected, for performing the deactivation moves;

5   if, in the previous step, less than N_{deact} cells have been finally selected, the missing cells are added, alternatively taking them from the two sets and starting from the one related to pilot pollution.

10 After having completed step 400 of building the neighbourhood of "nearby" solutions to the current solution, calling M_{act} and M_{deact} the selected cells, respectively for activation and deactivation (if the cell-based selection has been selected through parameter
15 32), the number of evaluated activation solutions (equal to Sol_{act}) and deactivation solutions (equal to Sol_{deact}) is expressed by the relationships:

$$Sol_{act} = \sum_{i=1}^{M_{act}} \binom{M_{act}}{i}$$

$$Sol_{deact} = \sum_{i=1}^{M_{deact}} \binom{M_{deact}}{i}$$

20 and corresponds to the complete set of possible activation and deactivation combinations of the selected cells (it must be noted how the evaluation of solutions obtained by simultaneous activation and deactivation of cells is not provided).

25

In case of site-based selection, related to the value assumed by parameter 32, the known operations described on cell base for building the deactivation neighbourhood (sub-neighbourhood) are extended to all sites having at
30 least one cell that satisfies the described conditions.

The algorithm "restore" procedure

Referring now to figure 5, the algorithm "restore" procedure is described in more detail, in case of cell-
5 based selection as established by the parameter or flag 32 value.

In step 2905 the restart procedure initialisation is performed. Such operation is divided into a first sub-
10 step 2910, in which the Evaluated Covered Area ("Area Coperta Stimata") parameter is set equal to the area covered by current solution starting from which the restart procedure is started, and a second sub-step 2915, in which the Evaluated carried Traffic ("Traffico
15 Smaltito Stimato") parameter is set equal to the traffic carried by current solution starting from which the restart procedure is started.

Then, in step 2920, a cell j is randomly extracted among
20 the inactive cells in current solution, such cell being activated in step 2925.

In step 2930 the update of estimations associated with the updated solution is performed. Such operation is
25 divided into a first sub-step 2935 for updating the Area Coperta Stimata, and a second sub-step 2940 for updating the Traffico Smaltito Stimato.

In step 2935 the updated value of Area Coperta Stimata is
30 obtained from the sum of current parameter value and the area covered by the randomly extracted cell in the configuration with all active candidate cells.

In step 2940 the updated value of Traffico Smaltito
35 Stimato is obtained from the sum of current parameter

value and traffic carried by the randomly extracted cell in the configuration with all active candidate cells.

At the end of the update sub-steps of covered area and carried traffic estimations, in step 2945 the satisfaction of project constraints by the estimations associated with the obtained solution is checked. If the estimations are satisfied, the procedure advances to step 2950, otherwise it returns to step 2920 and performs a new random cell extraction.

In step 2950, performances of the set of cells obtained during the "restore" step are evaluated through the deterministic evaluation module 14.

Afterwards, in step 2955, the real satisfaction of project constraints by the obtained solution is checked. If the constraints are satisfied, the "restore" procedure ends, restarting the optimisation process. Otherwise, step 2960 is performed in which Area Coperta Stimata and Traffico Smaltito Stimato are updated with covered area and carried traffic that have been evaluated in step 2950 and then, after having completed the update, a random cell extraction is again performed in step 2920.

In case of site-based selection, the cell-based described operations for the algorithm restore procedure are performed on a site-base.

Concluding, the present invention advantageously allows, in its preferred embodiment, performing the planning of a third-generation network by selecting a set of sites within a wider set of candidate sites, guaranteeing a solution that is able to simultaneously comply with the project constraints on the globally covered area and on

the globally carried traffic by selected sites, in addition to possible constraints referred to the searched optimum solution characteristics, such as for example the presence of compulsorily active cells and the need for
5 simultaneously activating/deactivating all cells in a site.

The present invention further allows performing the planning of a network guaranteeing a correct and
10 efficient operation of a mobile terminal during building the active set which lists the cells to which the terminal is connected in macro-diversity, because the pilot pollution phenomenon is also taken into account, operating in order to minimise it.
15
Obviously, the described methodology, that provides for subjecting to constraints both coverage and carried traffic, can be easily extended, by suitably adopting the parameters to be used in the cost function, for example,
20 for planning cellular networks of the GSM or second-generation types, and anyway for planning networks in cases in which the use of a site selection method can be assumed.

25 The described method and system can be used, for example, for planning third-generation networks, both by a mature operator already present in the mobile telephones market, and therefore with an installed network, and by a new operator.
30
In fact, a pre-existing operator will have available a presumably high set of sites, at least for the first network development steps, and will have, as main objective, that of deciding how many and which base radio
35 stations will have to be activated depending on the type

45

and amount of traffic being present in the territory considered by planning. Should it be decided to use all potentially available (candidate) base radio stations, there would be the best possible result in terms of radio
5 coverage and carried traffic, at the expense of a high cost of installed apparatuses and their bad use. In this case, the system would highly probably be characterised by the presence of many cells characterised by a low cell load level, namely with particularly low associated η_{cell}
10 and by a high pilot pollution incidence.

Lower costs with the same results, and therefore the same globally guaranteed radio coverage and carried traffic, could be obtained by not activating a certain number of
15 cells (or sites), whose carried traffic in the network configuration with all active candidate cells could be "captured" by stations adjacent thereto, not deactivated, that would be consequently characterised by a better exploitation of available capability. In such a
20 configuration, the system as a whole would better be used and therefore more efficient (in addition to being less costly).

A similar problem will occur in case of a new operator
25 for which it is important to establish how many cells are necessary for a good system design and where they will have to be installed. In this type of context, undoubtedly different from the one of a operator that already has a second-generation mobile network, an
30 efficient site selecting algorithm, operating on a set of points distributed on the territory in a relatively aimed way, can provide a valid support, in addition to the real step of planning the system, to the definition of the so-called site search areas, first major step in the radio

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designing process of a mobile cellular network.

Obviously, without changing the invention principle, the
embodiments and the realisation parts can be widely
5 changed with respect to what has been described and shown
merely as a non-limiting example, without departing from
the scope of the present invention as defined by the
enclosed claims.